Instructional and learning opportunities for remote offerings of integrated lab-lecture core undergraduate biomedical engineering courses

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Abstract

Emergency remote teaching in response to the COVID-19 pandemic had many challenges and a myriad of lessons learned, requiring critical self-assessment on the teaching process during the unplanned shift to remote instruction and to devise a strategy for future unplanned contingencies. In this manuscript, we reflect on the challenges faced, processes adopted after the remote transition, and lessons learned for two core courses in the Department of Biomedical Engineering at the University of Arkansas: Biomedical Instrumentation and Biomolecular Engineering. The Biomedical Instrumentation course is a sophomore-level, core course that encompasses both fundamentals of electric circuits as well as relevant physiological topics, with an overarching goal of teaching the basics behind modern measurement instrumentation in the context of biological systems. The Biomolecular Engineering course is a junior level, core course that begins with an introduction to the tools and techniques of molecular biology that are used for protein engineering. Additional topics include recombinant DNA techniques, biochemical kinetics, cell growth reaction and kinetics, bioreactors, membrane processes, and bioproduct purification. The two courses comprise three hours of lectures each week, and laboratory modules performed throughout the semester, the topics of which mostly parallel the topics covered during the lecture component.

Keywords

Remote learning, Inclusion, Laboratory

Challenge Statement:

We identified several challenges associated with the remote delivery of the Biomedical Instrumentation and Biomolecular Engineering courses based on instructors' experiences and post-hoc reviews of students' evaluations. Several students reported a lack of quality internet connection to follow course announcements, watch the video lectures, interact with their classmates or course instructor, and work on assignments. Other students exhibited a lack of digital literacy despite having access to both quality internet access and computers. Digital literacy widely misidentified and often referred to as device literacy- is the ability to obtain, assess, and generate information using information and communication technologies [1]. Being digitally literate requires the possession of both cognitive and technical skills. Based on this definition, we observed many students who struggled to deal with the new course format due to a lack of digital literacy.

As a result of the absence of face-to-face meetings, we received more comments that mentioned team members who were not contributing their fair share of the course assignments compared to baseline. Maintaining students' morale and motivation was an additional challenge. The students were understandably concerned about their health and their loved ones and showed a continued decrease in their motivation to focus on fulfilling the course objectives. The students' motivation was also affected by the announcement of a new grading policy that allowed the students to choose a pass/fail option for the grades instead of the traditional letter grade system.

Adapting the lab component of both courses for remote teaching was another challenge. The Biomolecular Engineering course has a classical hands-on lab component where the students prepare, conduct, and analyze experiments. To deliver content remotely, we recorded video demonstrations of the remaining lab experiments, provided sample data for the students to analyze, and assigned student teams to write lab reports based on the video recordings and the sample data. Some students reported that they did not fully grasp the lab principles discussed in the video. A verbatim comment from the students' evaluations was: "… sources of error, without performing the lab myself, I cannot guess where sources of error live within the lab itself, as I do not know where mistakes could have been made in the procedure." In the Biomedical Instrumentation course, suspension of in-person classes resulted in a lack of hands-on laboratory sessions to demonstrate applications of electronic circuit theory to the real-world problem of sensing electrocardiogram (EKG) signals, filtering and amplifying those signals, and acquiring and digitizing them.

Novel Initiative:

A combination of synchronous/asynchronous instruction was adopted to address internet connectivity issues. Lectures were recorded using the Kaltura Video Platform and uploaded to the learning management system (LMS: Blackboard). Before the suspension of in-person teaching, the University provided access and training to use this video recording system. The availability of recorded lectures and video announcements allowed the students the flexibility to schedule their learning time amongst their travel, relocation, and work; and to deal with the challenges of living at home with family. This is remarkable considering the student population in our department comprises ~20% first-generation college students as well as students from low-income families. Additionally, live streaming sessions were introduced to enable the students to interact with the instructor in real-time. Initially, some students reported a loss of motivation to study because there was no set schedule for them to attend the lectures and also because they lost the in-person interaction with instructors and classmates.

With the introduction of a pass/fail grading option campus-wide, instructors were faced with the burden of maintaining student interest. We frequently posted informal short video announcements that emphasized the importance of self-care while implying the importance of meeting the re-designed course objectives and ensured that students worry less about grades. The informal friendly video announcements had the instructor showing up to update the students about course assignments or exams. Several students mentioned that the announcements helped them destress while being effective in delivering the message. A verbatim comment from one of the students mentioned "… seeing (the videos) has definitely lightened the mood surrounding this big change …".

One of the key objectives in both courses is for students to function effectively on a team while developing leadership and communication skills within a collaborative and inclusive environment. We used the LMS (Blackboard) Collaborate feature to open a collaboration room that the students could use to meet virtually at any time. This feature allowed students to meet virtually using the same learning management system that they normally used to keep up with the other courses without concern about exchanging personal contact information or using other unsupported meeting systems. The collaboration room allowed the instructional team to create breakout rooms for different teams and visit these rooms when questions arise. Also, student teams were able to rehearse the term project presentations together by sharing their computer screens and camera with their colleagues and also record the final presentation and upload it to the respective course assignment.

At the time in-person teaching was suspended, the Biomolecular Engineering course, out of nine labs, had three left to be conducted. Since the experiments were well-established from previous years of instruction (as well as an abundance of video resources found online), we decided to produce videos to demonstrate the experimental protocols being implemented. We augmented that with detailed video explanations of the experimental steps recorded by the Lab teaching assistants. Further, we provided the students with datasets to conduct the experimental analysis and write the lab report accordingly. For the Biomedical Instrumentation course, the remaining laboratory modules were re-formatted to include the same topics as planned, but with original data files supplied in Excel documents to student groups. Student groups remained the same as previously assigned, but all worked remotely from their respective homes and submitted their laboratory reports online. The companion lecture series was continued, distributed online to students live (and also via recording) through the Blackboard Collaborate platform.

Reflections:

Preparing the digitally literate student is extremely crucial especially during the testing times of a global pandemic. Educators must keep that in mind while redesigning remote teaching environments; and also actively determine possible points of failure in technologies. A dedicated course module should introduce the students to the technologies that will be used in the course. Instructors should never assume that the students are cognitively and technically ready to deal with the digital world; in fact, they must dedicate time to instill the true meaning of digital literacy into the next generations of students.

A significant challenge that remains is teaching the hands-on lab components; our approach to video-record the lab procedures and provide datasets from previous years to the students was quickly adopted as a contingency measure. However, it should be considered less effective in meeting the objectives of these lab assignments as evidenced by our students' evaluations of instruction. The primary positive outcome of this approach- successfully covering all of the materials originally planned for the semester- was possible due to the long history of these courses and data acquired from previous years' teaching experiences, which allowed us to share uniform and quality sample data for the "at-home" laboratory modules for all student groups. A neutral outcome of this approach was the continued team-based approach. While most students were able to successfully collaborate online, several groups had difficulty working with some of their members due to the challenges described above. A significant negative outcome was primarily described as a lack of hands-on learning throughout the laboratory modules. Some students specifically mentioned not understanding from the beginning how breadboards are used in electronic circuits. This is typically something students master throughout the semester by building circuits as described in the laboratory manual and inevitably going "off-script" in order to experiment on their own. Additional specific negative outcomes were a lack of observing "real-world" limitations in applying their simple EKG measurement circuits- by understanding how measurement noise can be amplified to exceed the signal of the EKG itself as well as how movement artifacts are caused by human subject motion. Both (1) self-experimentation and (2) observation of real-world challenges to building electronic instrumentation are fundamental to understanding the basic principles behind many biomedical engineering applications. Similarly in the biomolecular engineering course, the students were not able to experience how the proteins were separated in the gel electrophoresis apparatus in real-time and when things normally do not go well during the lab, they did not experiment with different troubleshooting techniques.

Future remote delivery of the Biomolecular Engineering course laboratory will require the utilization of contemporary technologies like virtual and augmented reality. This is certainly needed to prepare for the next emergency as it is not practical to work with biohazardous materials such as mammalian or bacterial cultures at home in these courses. Remote delivery of the Biomedical Instrumentation course will benefit from the emergence of inexpensive board-level computers (Raspberry Pi) and home electronics and automation kits (Arduino). It should be feasible to construct a course-specific laboratory setup that will directly address self-experimentation and observation of real-world challenges by allowing students to build their own simple circuits and data acquisition devices at home. Myriad descriptions for such low-cost EKG measurement applications exist, but for the University of Arkansas-specific course, the high-level requirements would be to 1) allow students to build and make simple measurements of DC and AC circuits (including amplifiers and filters) and 2) acquire analog voltage signals and digitize them for subsequent analysis. This can be accomplished using simple components and a breadboard, a programmable Arduino board with analog and digital in/out capabilities, and inexpensive disposable EKG leads. Students could still work in teams, but a standardized approach that allows students to work asynchronously would facilitate collaboration. Student learning theory has demonstrated the value of hands-on learning in undergraduate science labs and can guide more effective instruction within the scope of Biomedical Engineering if learning at home with the above-described methods [2]. Specifically, following laboratory assignments that are broad in scope, with less prescribed steps will foster a more explorative and engaging experience, and will be adopted when revising laboratory manuals for the future [3]. Furthermore, more synchrony with the conventional didactic lectures can be pursued since students will be able to learn at home and not subject to scheduling conflicts that require each lab session to be spread among several sections. This has been shown to produce favorable outcomes in undergraduate science labs [4]. Finally, it is important to ensure that students are actively attending when learning in a remote environment. Although not a technical challenge, it is a continuous pedagogical challenge and undoubtedly requires effort to design active learning formal and informal approaches that promote an inclusive learning environment. It is thus important that all integrated lab-lecture biomedical engineering courses be designed to enable instructors to foster connections with students in an empathetic manner and ensure the active fulfillment of learning outcomes.

References:

[1] L. Heitin, "What is digital literacy," *Educ. Week*, vol. 36, no. 12, pp. 5–6, 2016.

[2] J. Bernhard, "What matters for students' learning in the laboratory? Do not neglect the role of experimental equipment!," *Instr. Sci.*, vol. 46, no. 6, pp. 819–846, Dec. 2018, doi: 10.1007/s11251-018-9469-x.

[3] R. M. Felder and S. W. Peretti, "Learning theory-based approach to the undergraduate laboratory," *ASEE Annu. Conf. Proc.*, vol. 3, p. 2, 1998.

[4] C. B. Russell and G. Weaver, "Student Perceptions of the Purpose and Function of the Laboratory in Science: A Grounded Theory Study," *Int. J. Scholarsh. Teach. Learn.*, vol. 2, no. 2, 2008, doi: 10.20429/ijsotl.2008.020209.

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